ARE THERE TWO SORTS OF TYPE IA SUPERNOVA?

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OUTLINE

- Review of claims in Milne et al. (2015)
- Milne-like model vs. Salt II model of SNIa
- Expectations in SDSS and SNLS and compare with data
- To be done

THE CHANGING FRACTIONS OF TYPE IA SUPERNOVA NUV–OPTICAL SUBCLASSES WITH REDSHIFT

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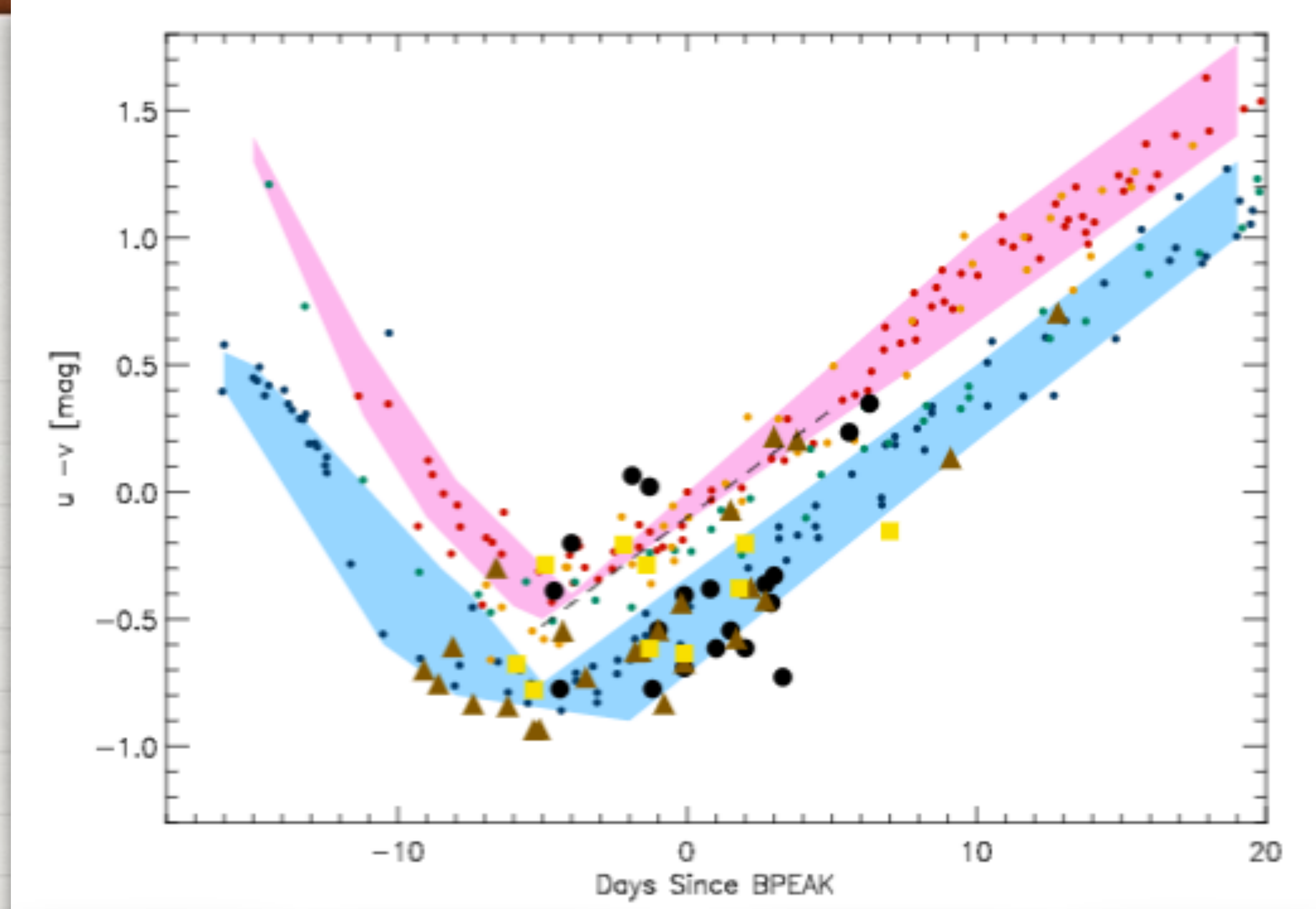
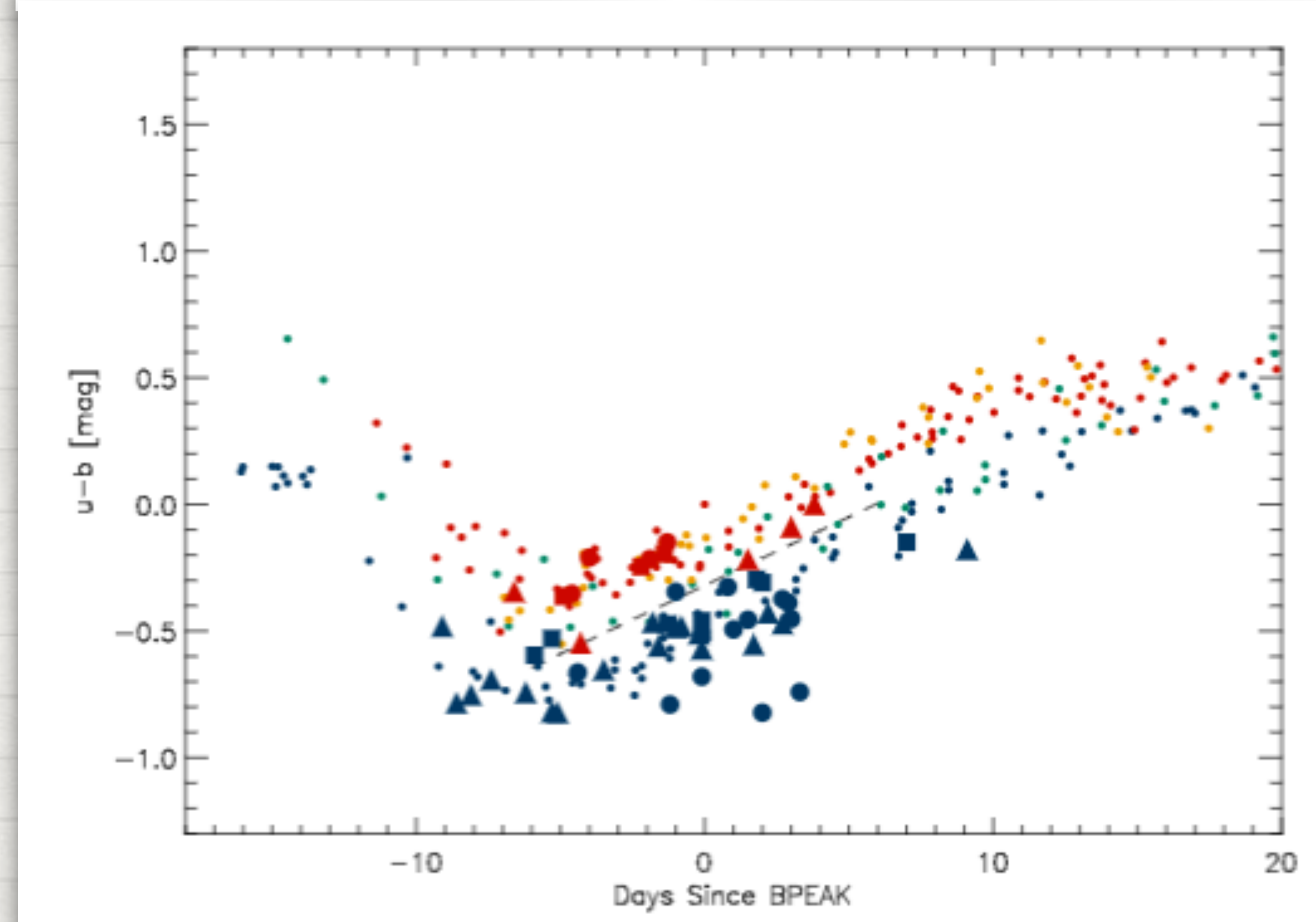
Abstract

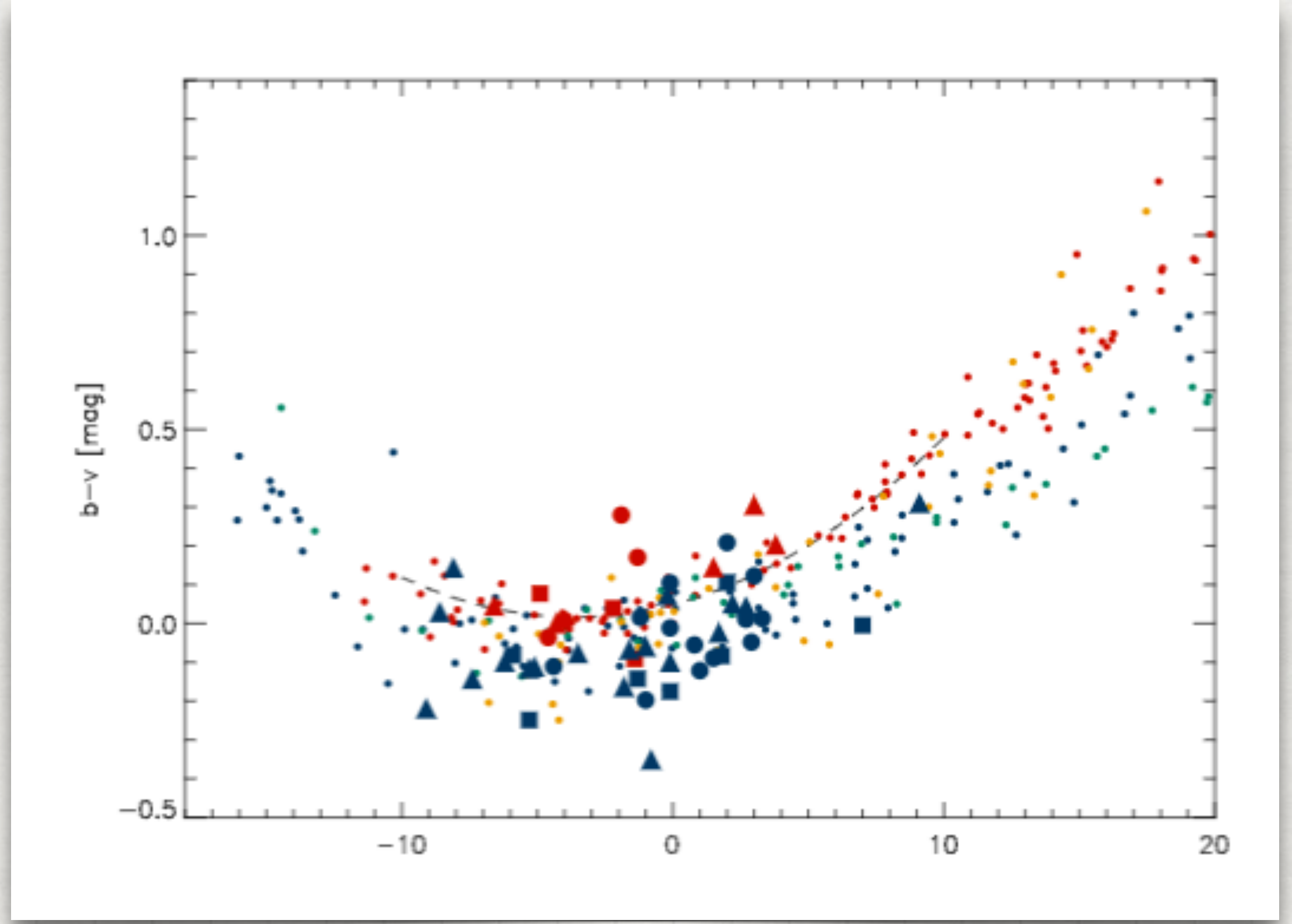
Ultraviolet (UV) and optical photometry of Type Ia supernovae (SNe Ia) at low redshift have revealed the existence of two distinct color groups, composed of NUV-red and NUV-blue events. The color curves differ primarily by an offset, with the NUV-blue $u - v$ color curves bluer than the NUV-red curves by 0.4 mag. For a sample of 23 low-redshift SNe Ia observed with *Swift*, the NUV-red group dominates by a ratio of 2:1. We compare rest-frame UV/optical spectrophotometry of intermediate- and high-redshift SNe Ia with UVOT photometry and *Hubble Space Telescope* spectrophotometry of low-redshift SNe Ia, finding that the same two color groups exist at higher redshift, but with the NUV-blue events as the dominant group. Within each red/blue group, we do not detect any offset in color for different redshifts, providing insight into how SN Ia UV emission evolves with redshift. Through spectral comparisons of SNe Ia with similar peak width and phase, we explore the wavelength range that produces the UV/optical color differences. We show that the ejecta velocity of NUV-red supernovae (SNe) is larger than that of NUV-blue objects by roughly 12% on average. This velocity difference can explain some of the UV/optical color difference, but differences in the strengths of spectral features seen in mean spectra require additional explanation. Because of the slightly different $b - v$ colors for these groups, *NUV-red SNe will have their extinction underestimated using common techniques*. This, in turn, leads to underestimation of the optical luminosity of the NUV-blue SNe Ia, in particular, for the high-redshift cosmological sample. Not accounting for this effect should thus produce a distance bias that increases with redshift and could significantly bias measurements of cosmological parameters.

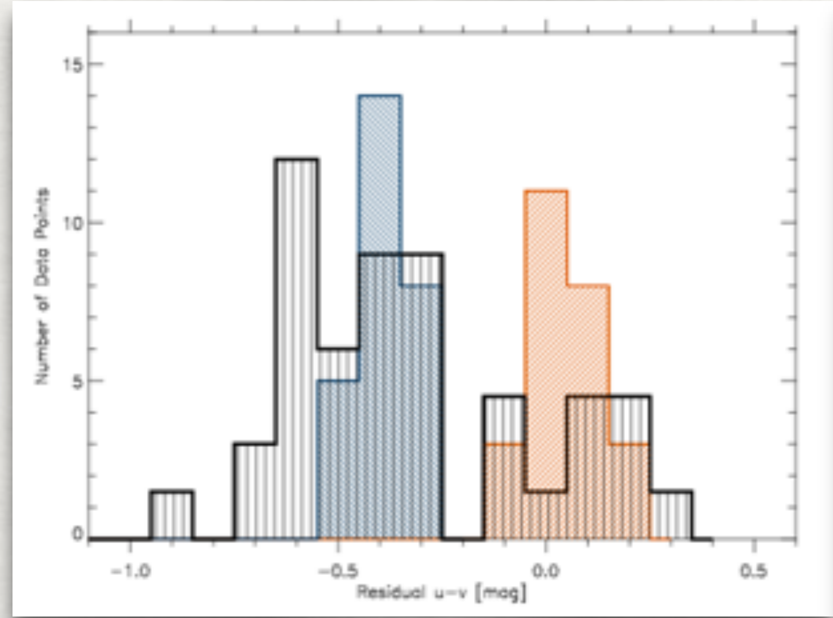
- Paper uses spectrophotometry from the UVOT telescope to observe the light curves of 50 SNIa
- Observe two distinct bands in the rest frame U-V color light curve.
- Break the sample into two sets (red and blue).
- See smaller but still clear separation between the two samples in the U-B color light curve.

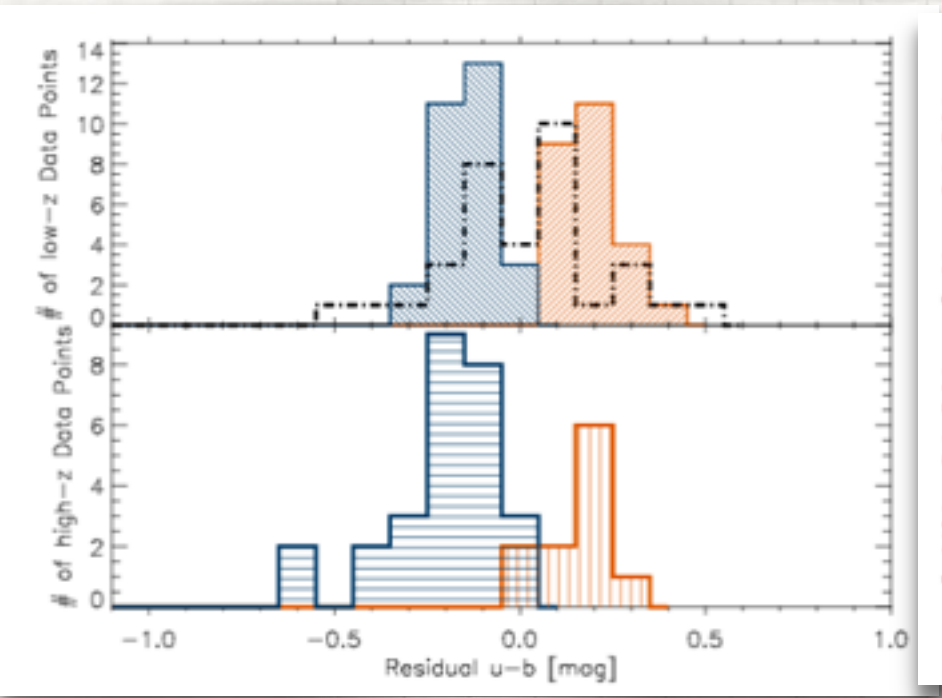


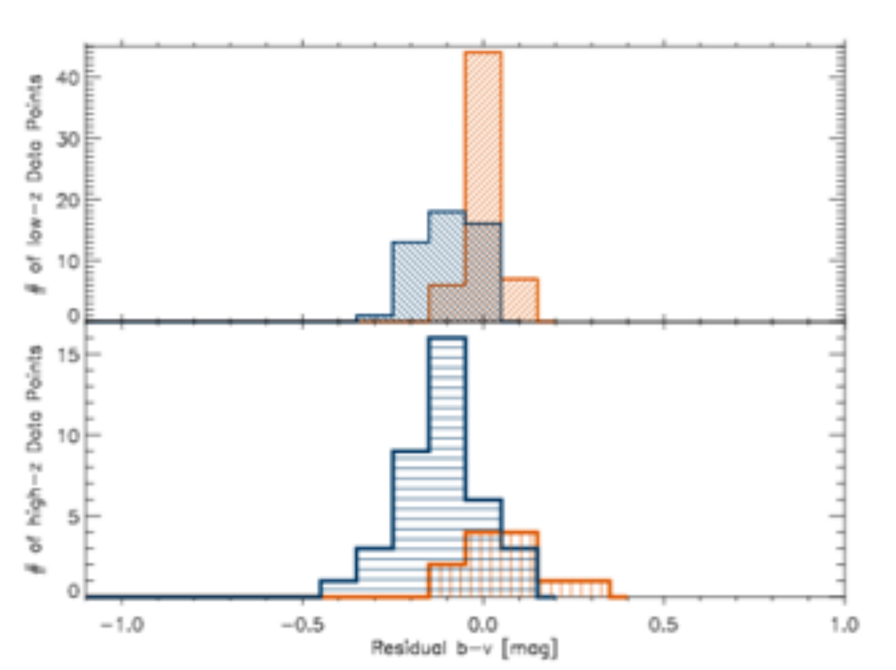


- Separation mostly disappears in the B-V color.
- See the effect most clearly in the colors at B-peak with about 0.4 mag separation in U-V, 0.2 mag in U-B, and small in B-V.
- Explained by the ultra-violet part of the spectrum being different in red and blue.





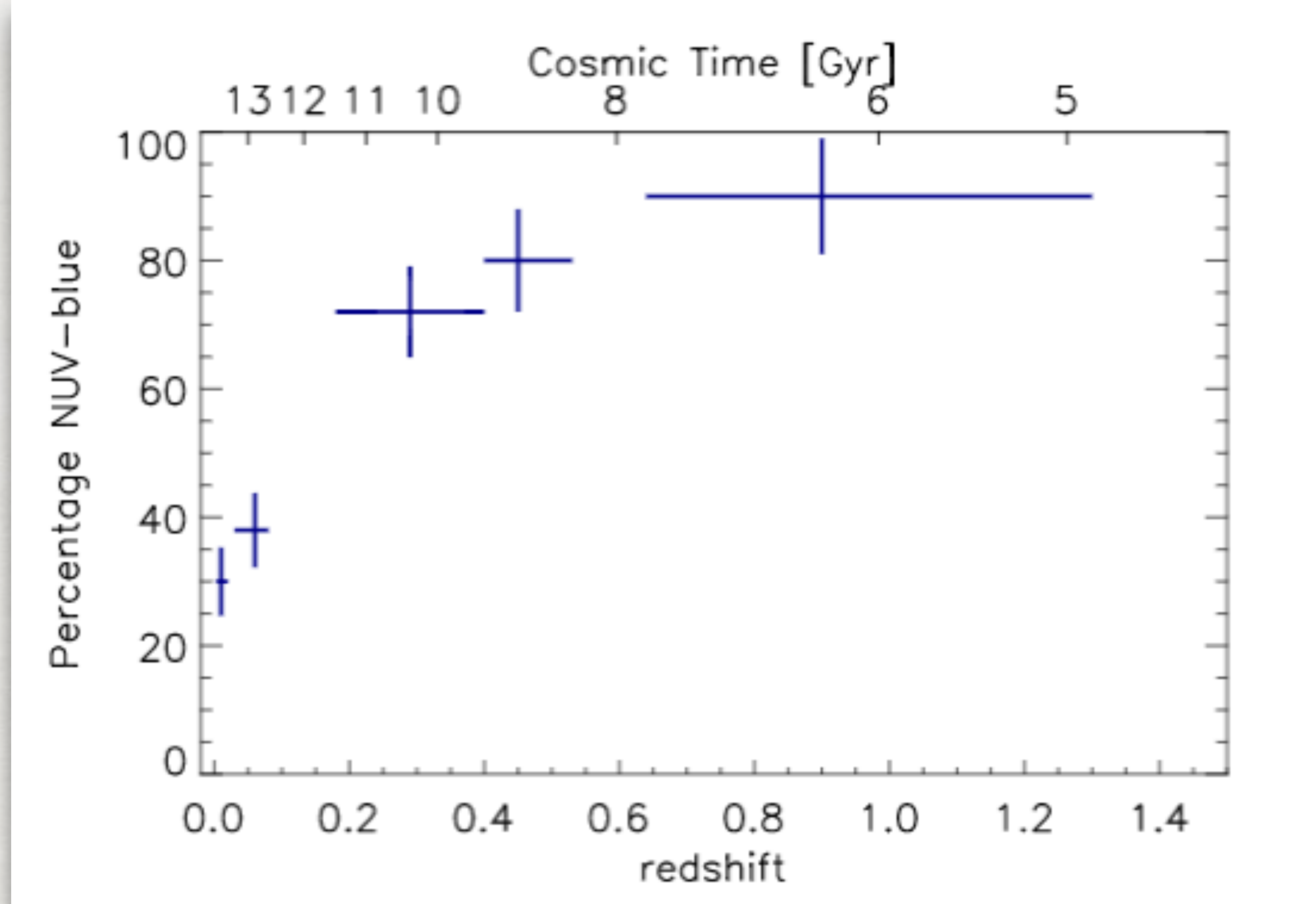


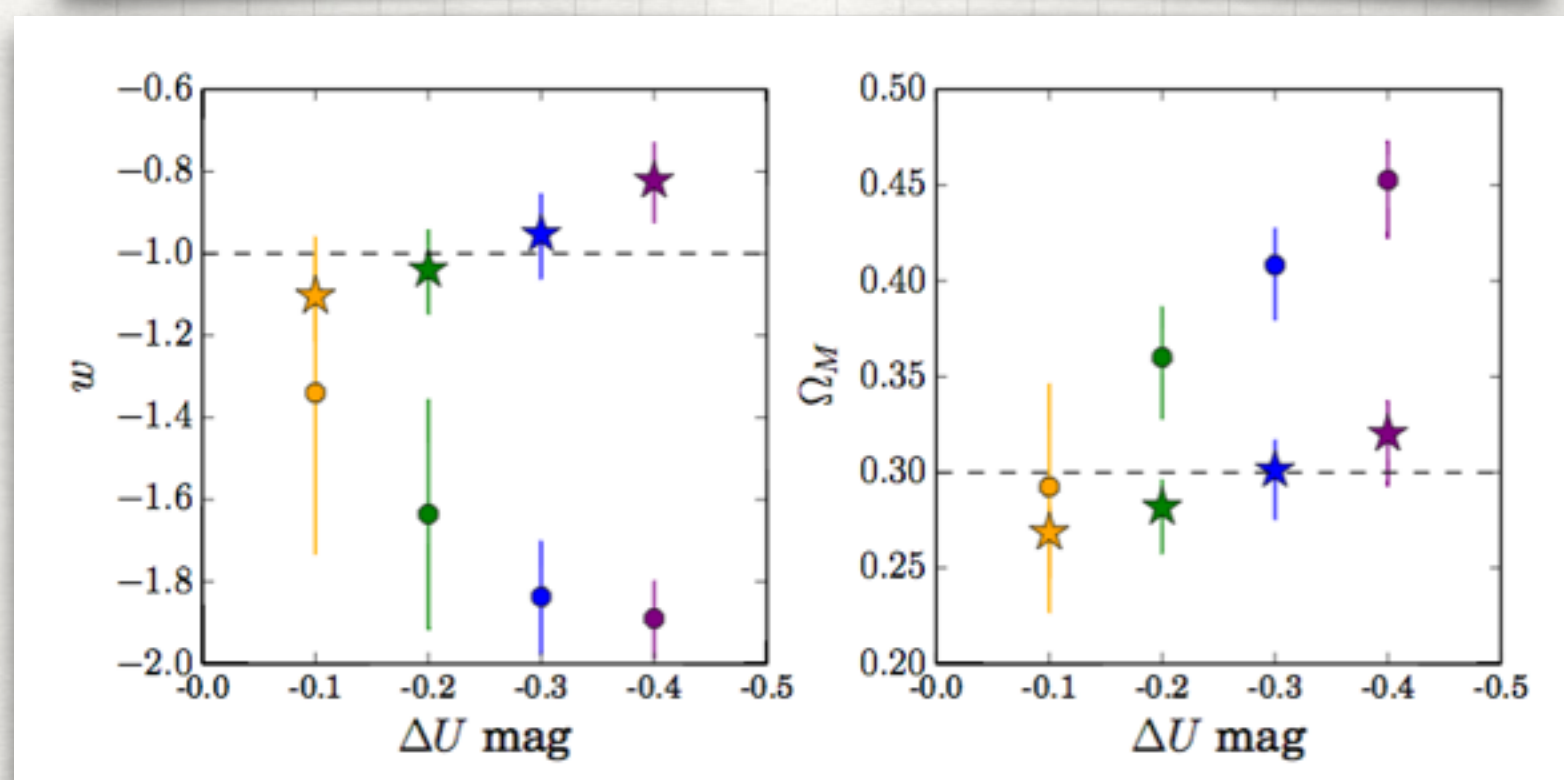


- The fraction of blue-types and red-types changes versus redshift.

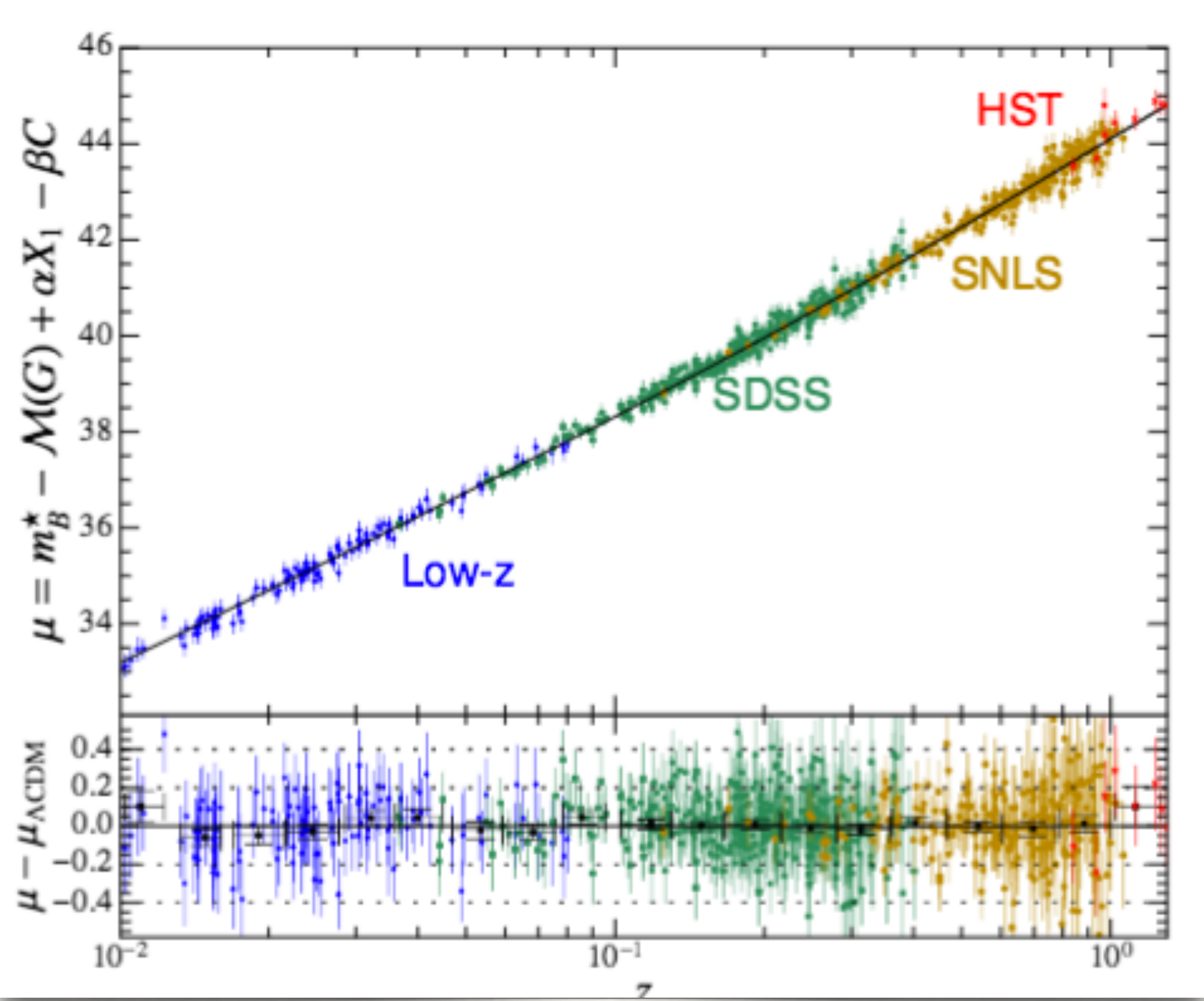
- Milne et al. go on to look at the spectra of the SNIa and try to correlate the red and blue samples with spectral features and find that that the blue sample has lower ejecta velocity than the red.

- If true it leads to a large bias in the extraction of cosmology parameters from SNIa.



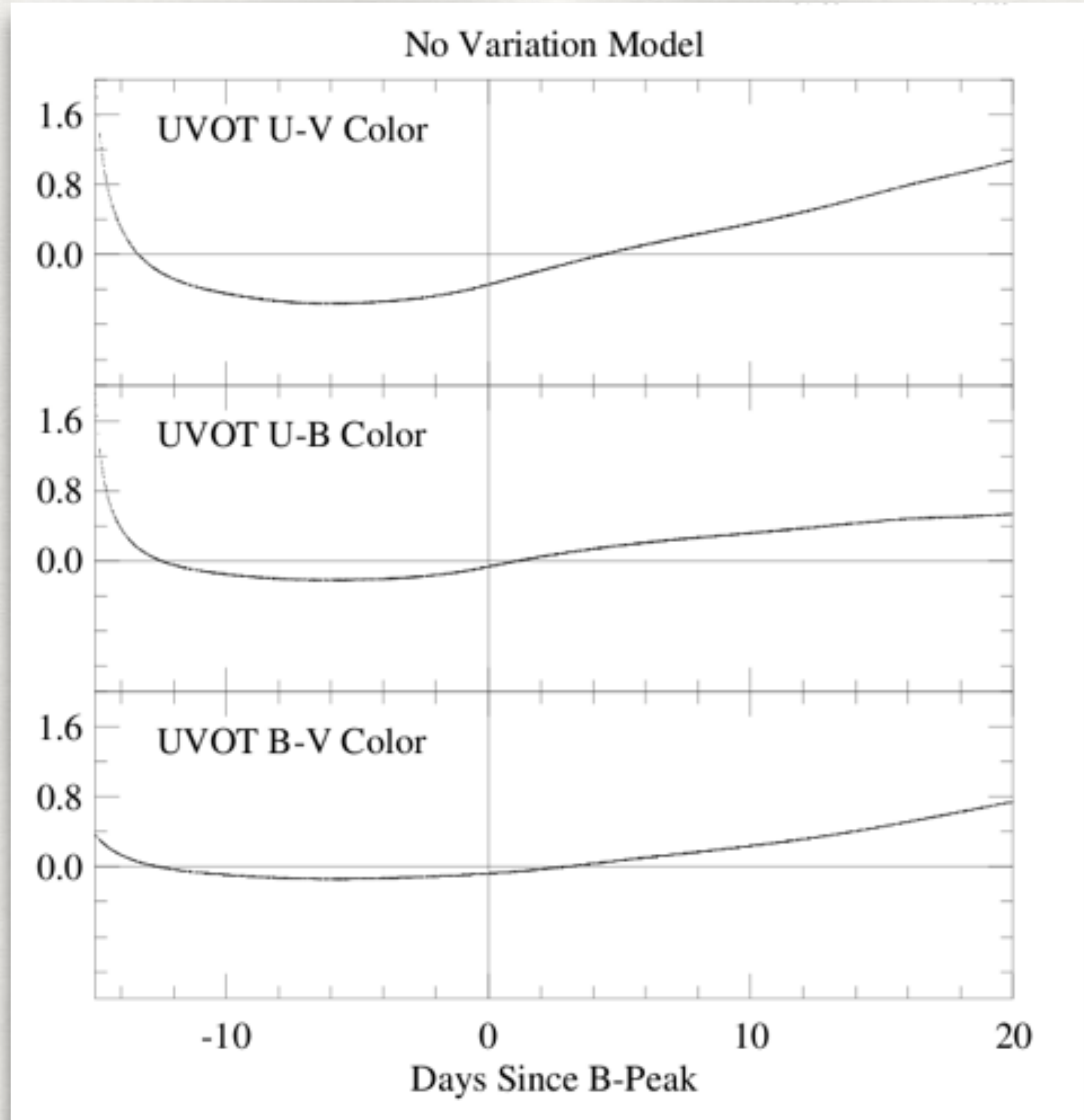


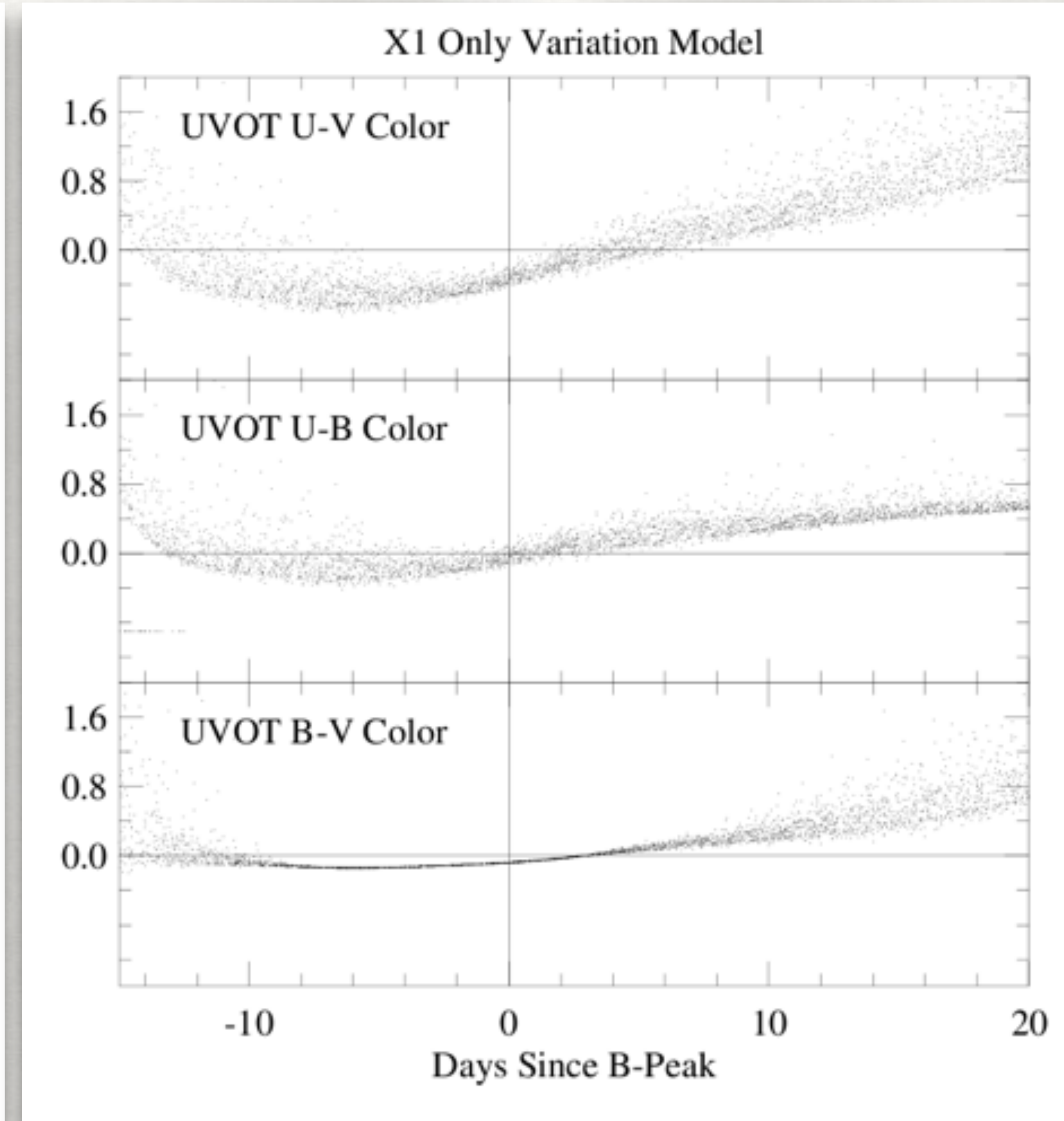
- Claim is kind of startling.
- SDSS and SNLS cosmology samples in the Joint Light curve Analysis (JLA) (M. Betoule et al. 2014 A&A, 568, A22) (I am a co-author and was an internal reviewer) used 740 SNIa in the redshift range 0.05<z<0.4 (SDSS) and 0.2<z<1.0(SNLS).
- From 0.3<z<0.7 the ultra-violet part of the rest frame spectrum is redshifted into the optical where the SDSS and SNLS have their most sensitive filters.
- We should have noticed >10% of the sample with a bimodal rest frame ultra-violet brightness.

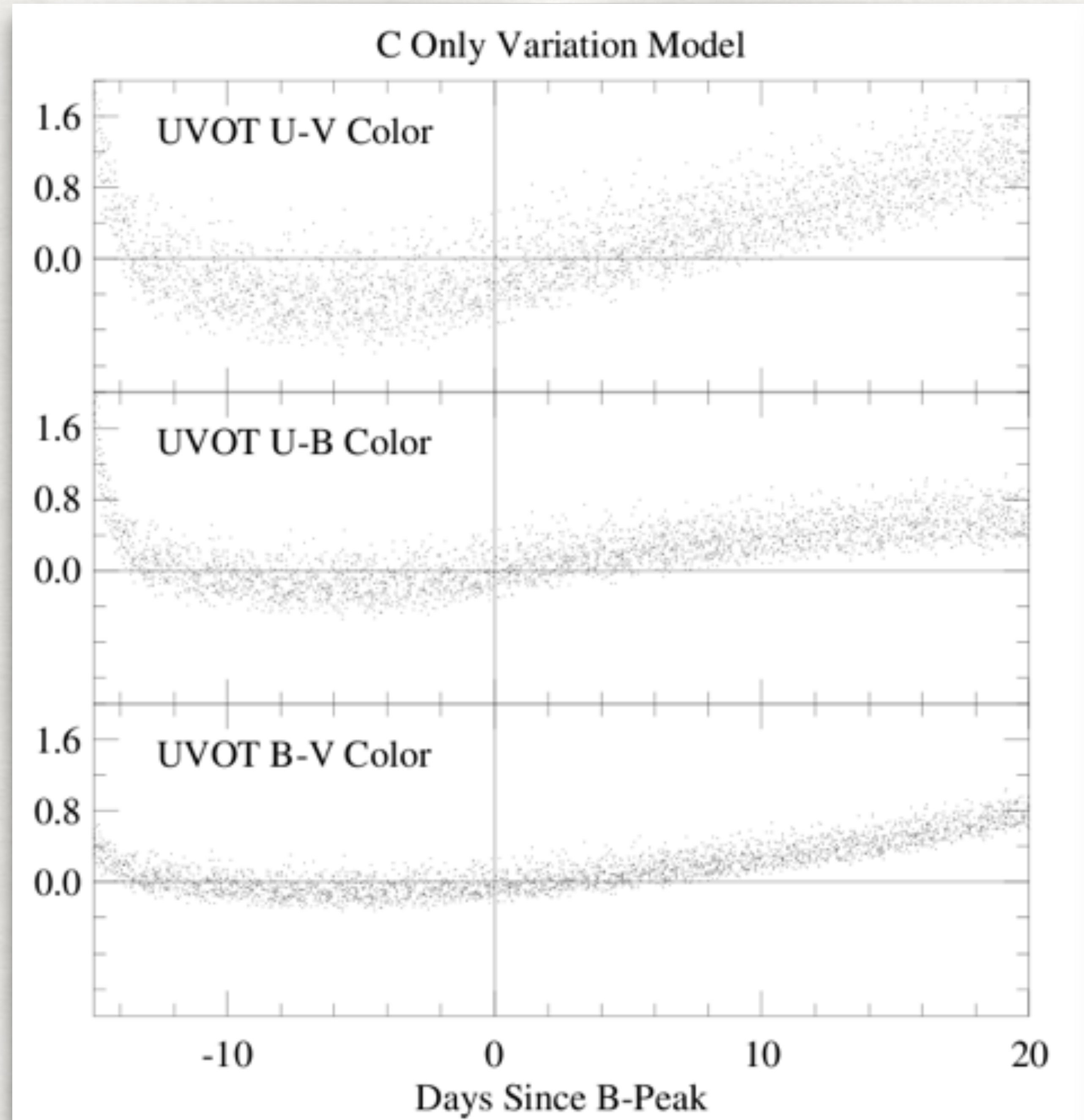


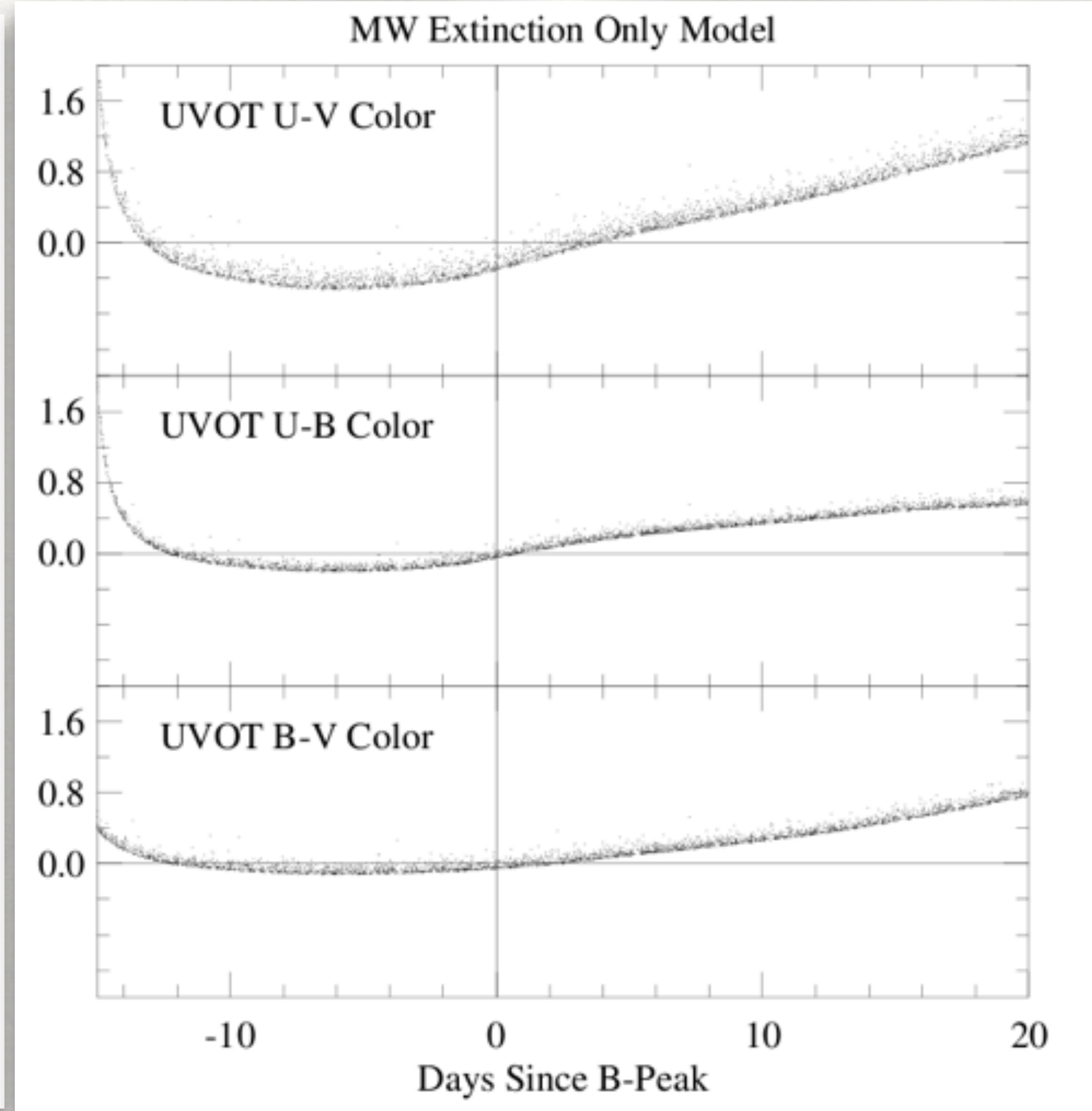
MODELING THE MILNE EFFECT

- Begin with the UVOT filters (provided by Milne)
- Use the Salt-II model of J. Guy et al.
- It has two parameters, X1 or stretch, and c, color.
- Also there is extinction by the Milky Way that will dim and redden.
- See the effect of the basic model and letting its parameters vary as seen in JLA
- All done with SNANA, SuperNova ANAlysis package of R. Kessler et al.

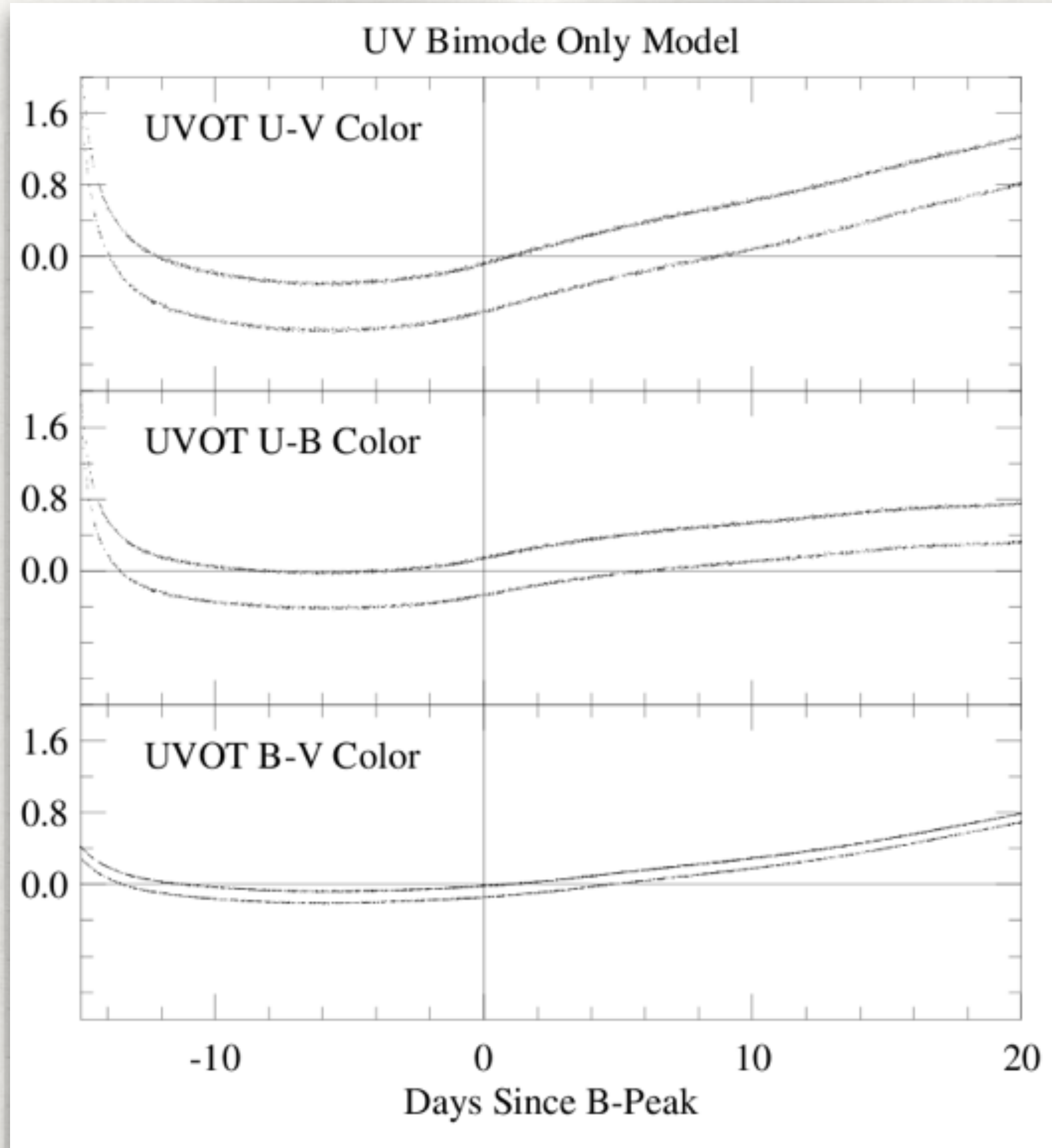

No Variation Model
UVOT U-V Color
UVOT U-B Color
UVOT B-V Color
1.6
0.8
0.0
-10
0
10
20
Days Since B-Peak


X1 Only Variation Model
UVOT U-V Color
UVOT U-B Color
UVOT B-V Color
1.6
0.8
0.0
-10
0
10
20
Days Since B-Peak

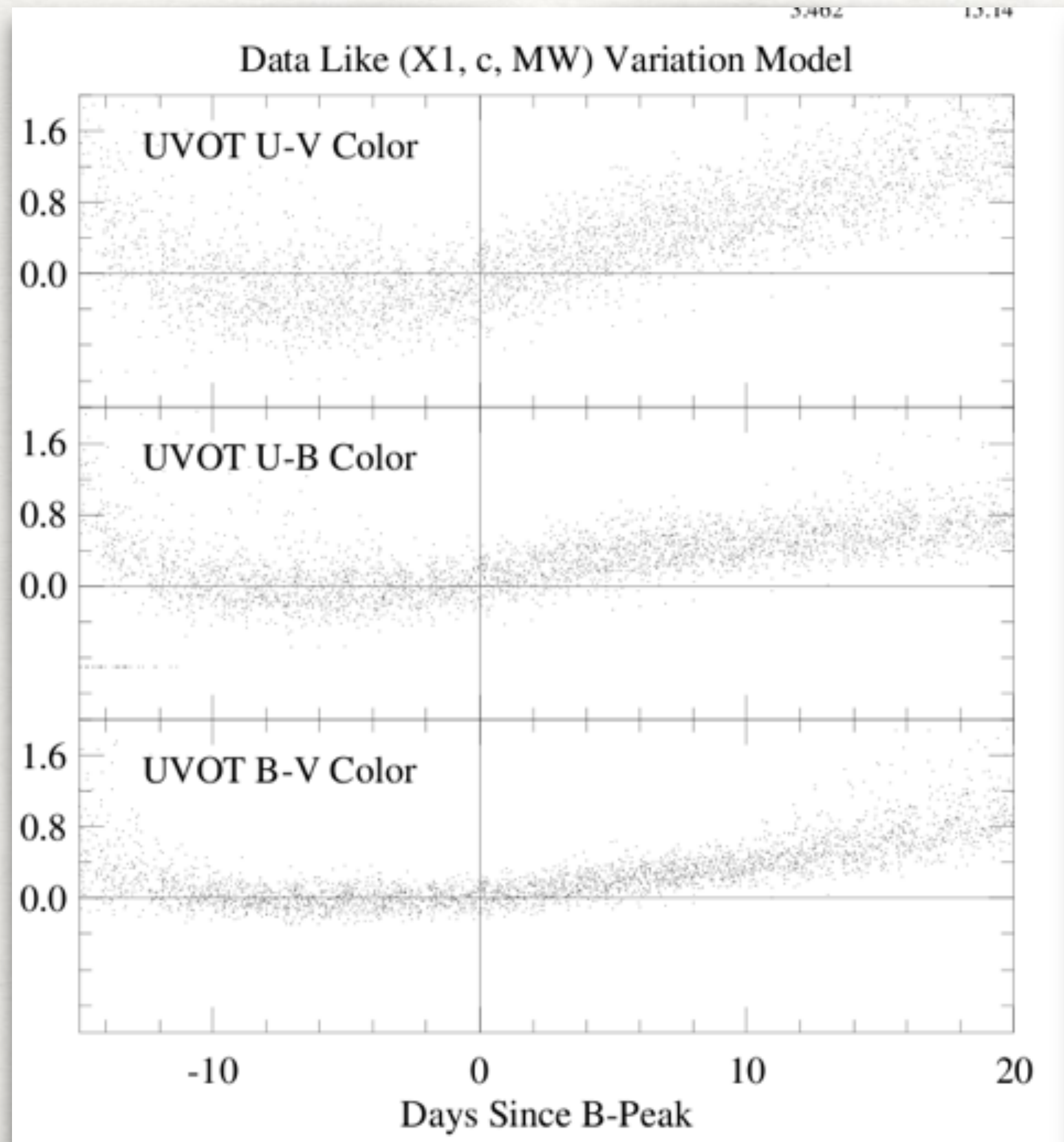

C Only Variation Model
UVOT U-V Color
UVOT U-B Color
UVOT B-V Color
1.6
0.8
0.0
-10
0
10
20
Days Since B-Peak

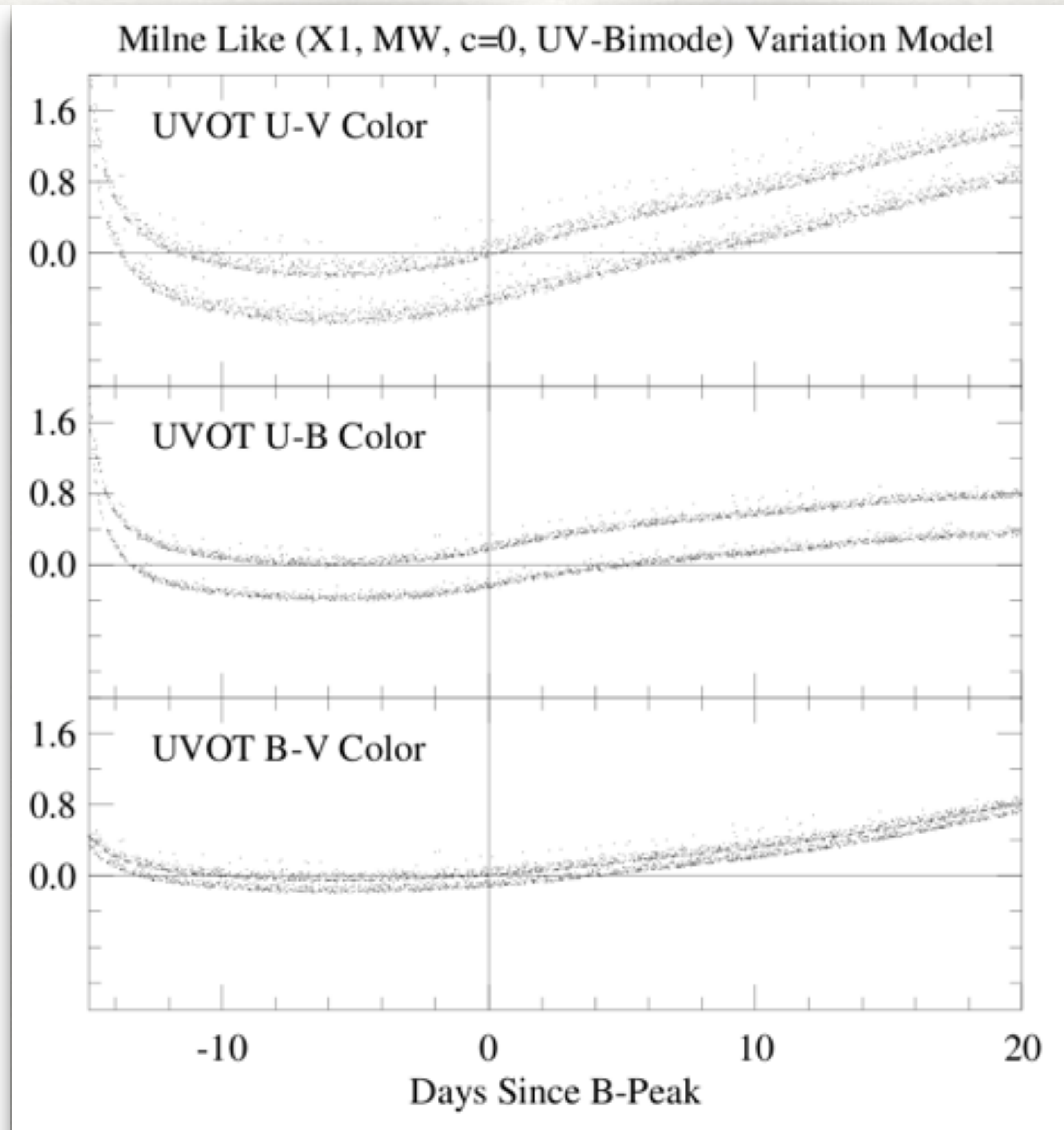

MW Extinction Only Model
UVOT U-V Color
UVOT U-B Color
UVOT B-V Color
1.6
0.8
0.0
-10
0
10
20
Days Since B-Peak

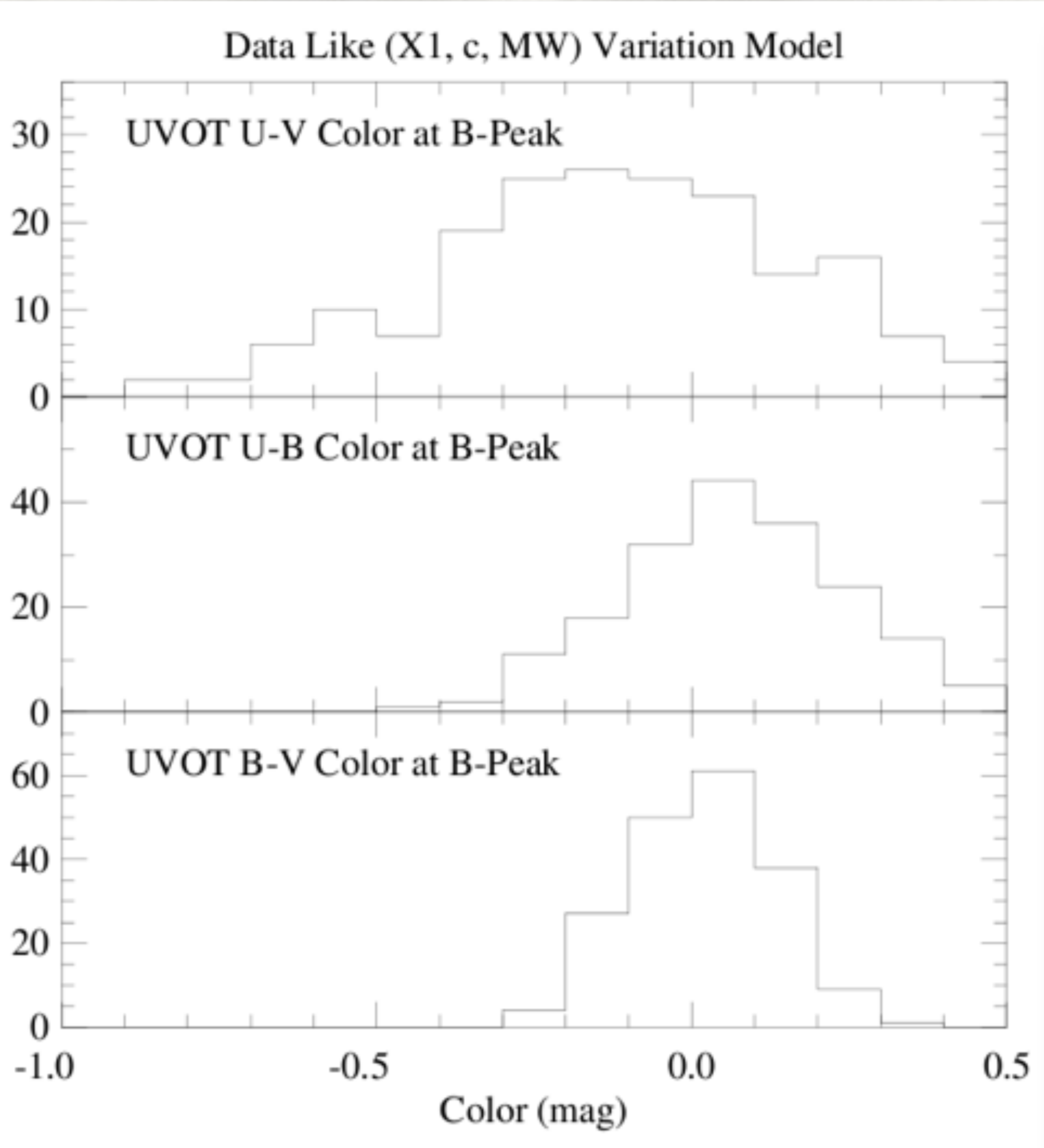
- Add a ultra-violet bimodal model to simulate Milne's claim.

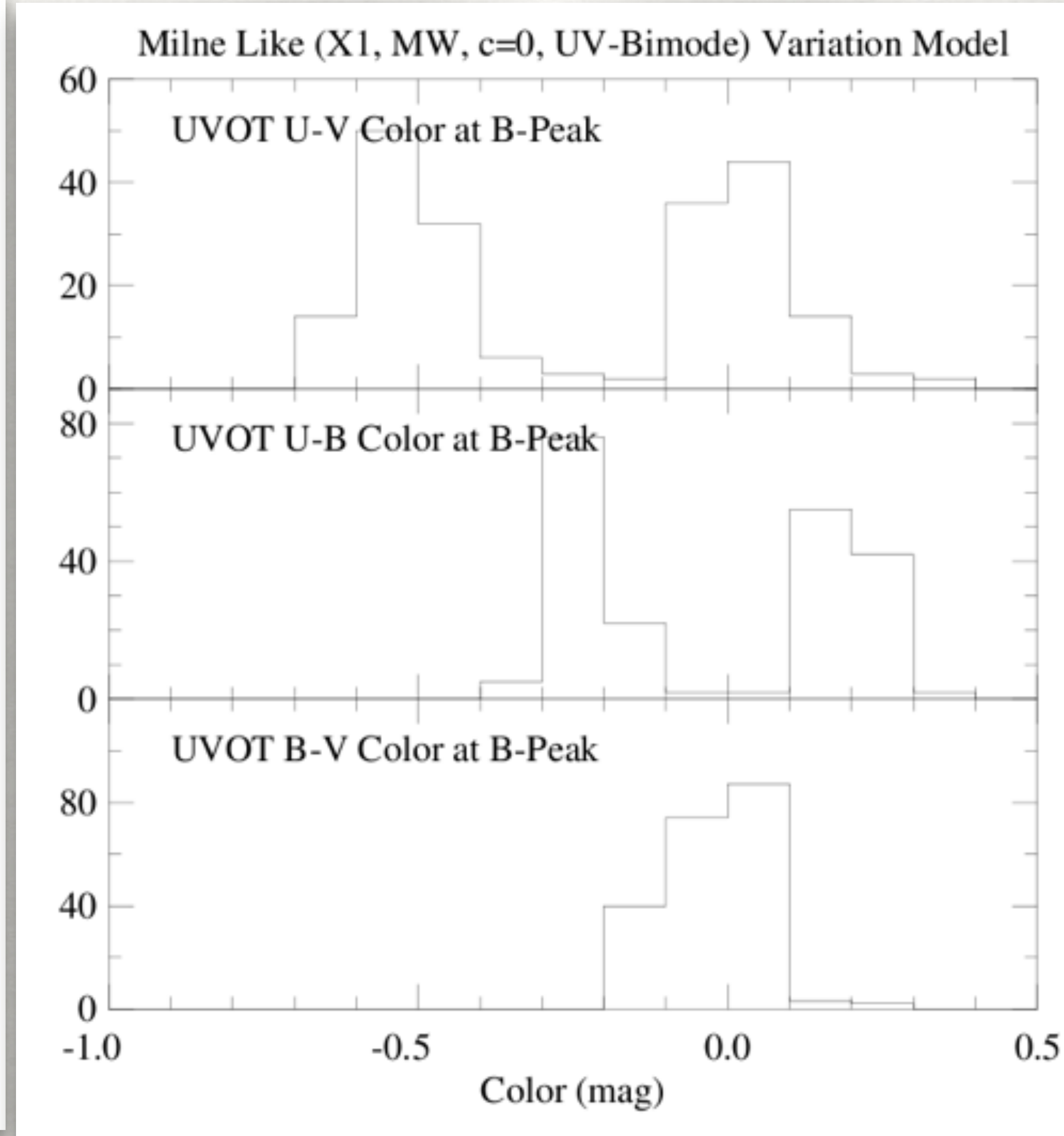


- Simulate two models, Salt II, where we allow X1 and c variation plus Milky Way extinction versus Milne-like, where we allow X1 variation, c is fixed to 0.0 plus Milky Way extinction and ultra-violet bimodal.



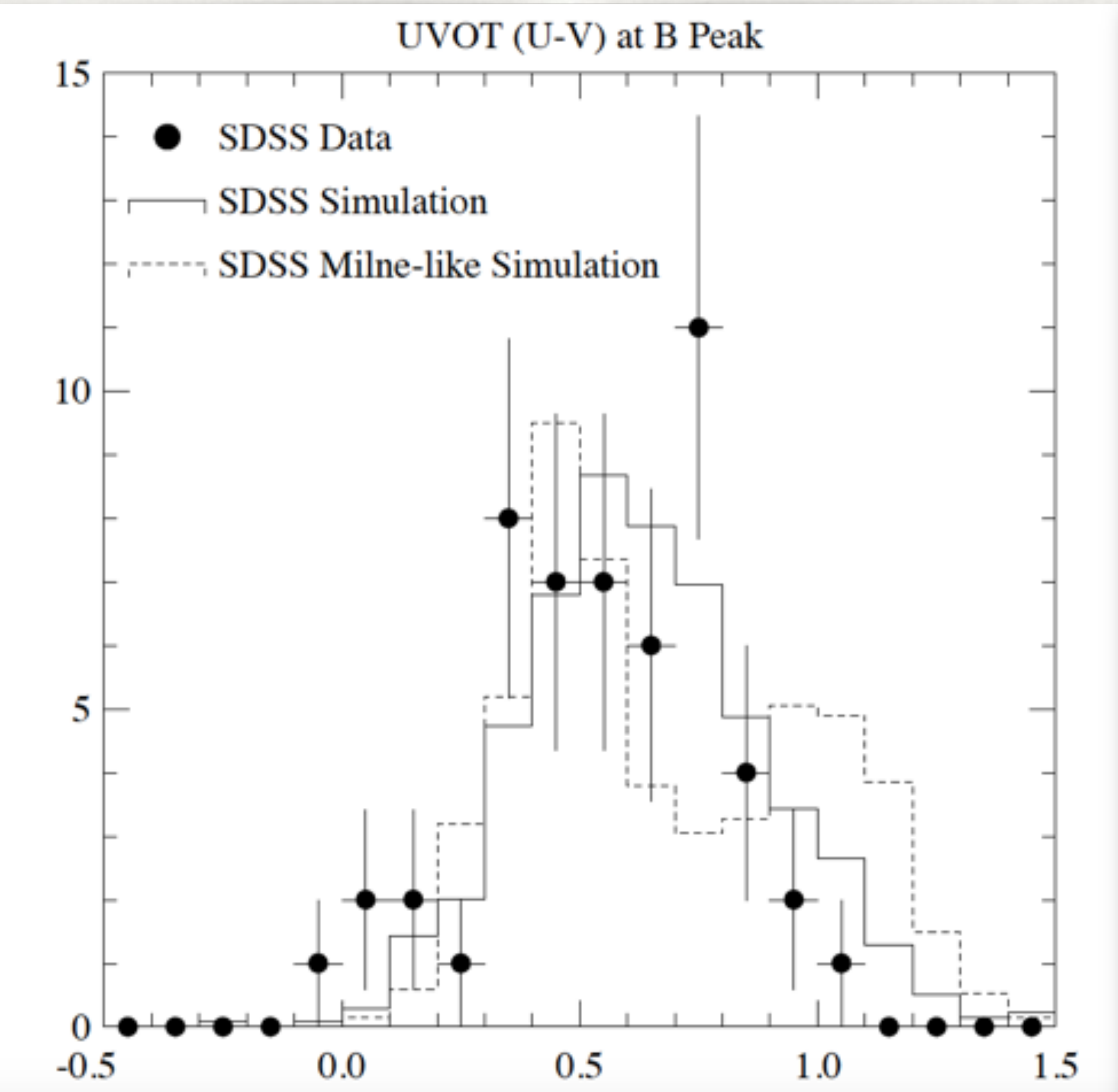


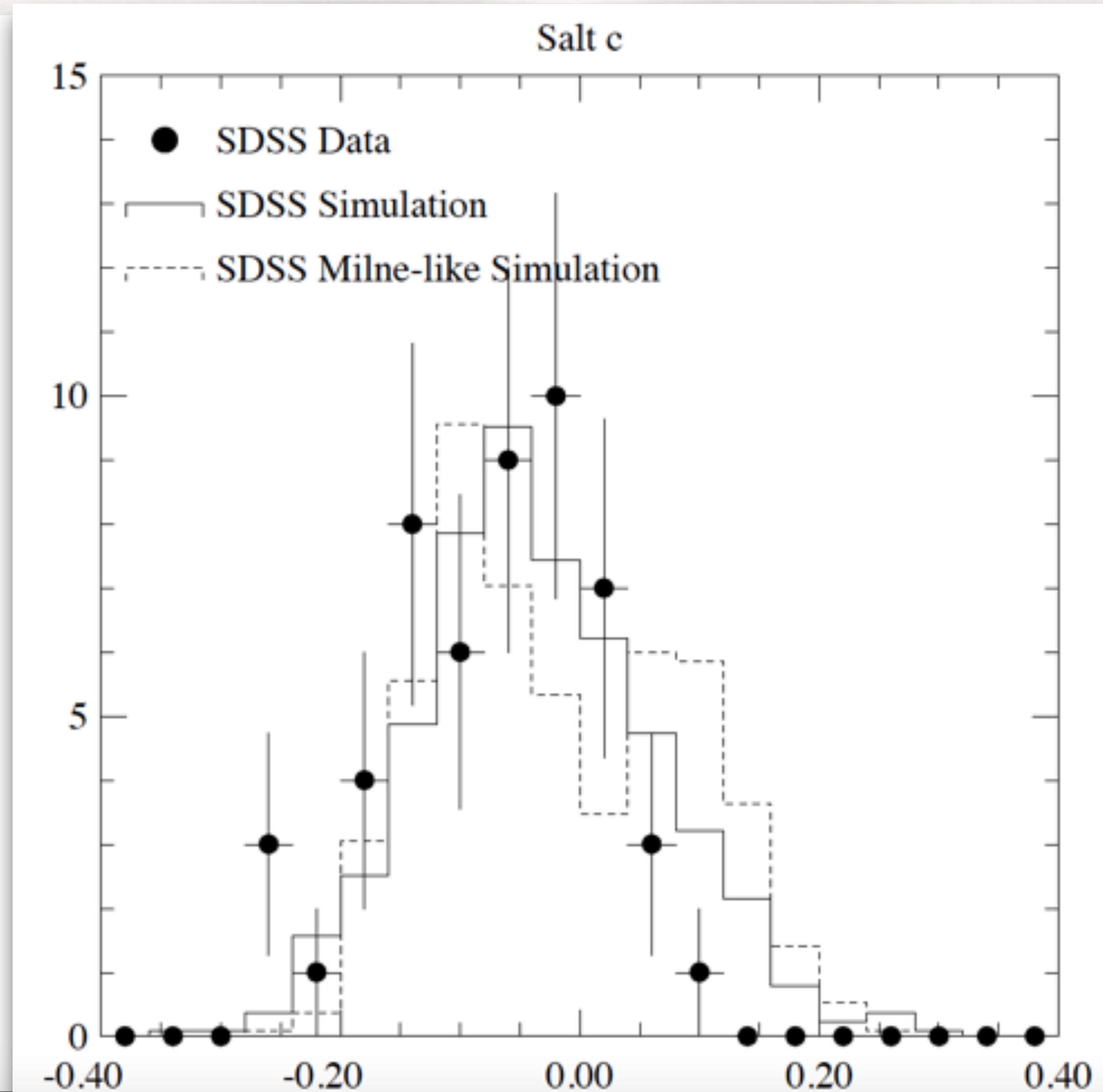

Data Like (X1, c, MW) Variation Model
UVOT U-V Color at B-Peak
UVOT U-B Color at B-Peak
UVOT B-V Color at B-Peak
Color (mag)

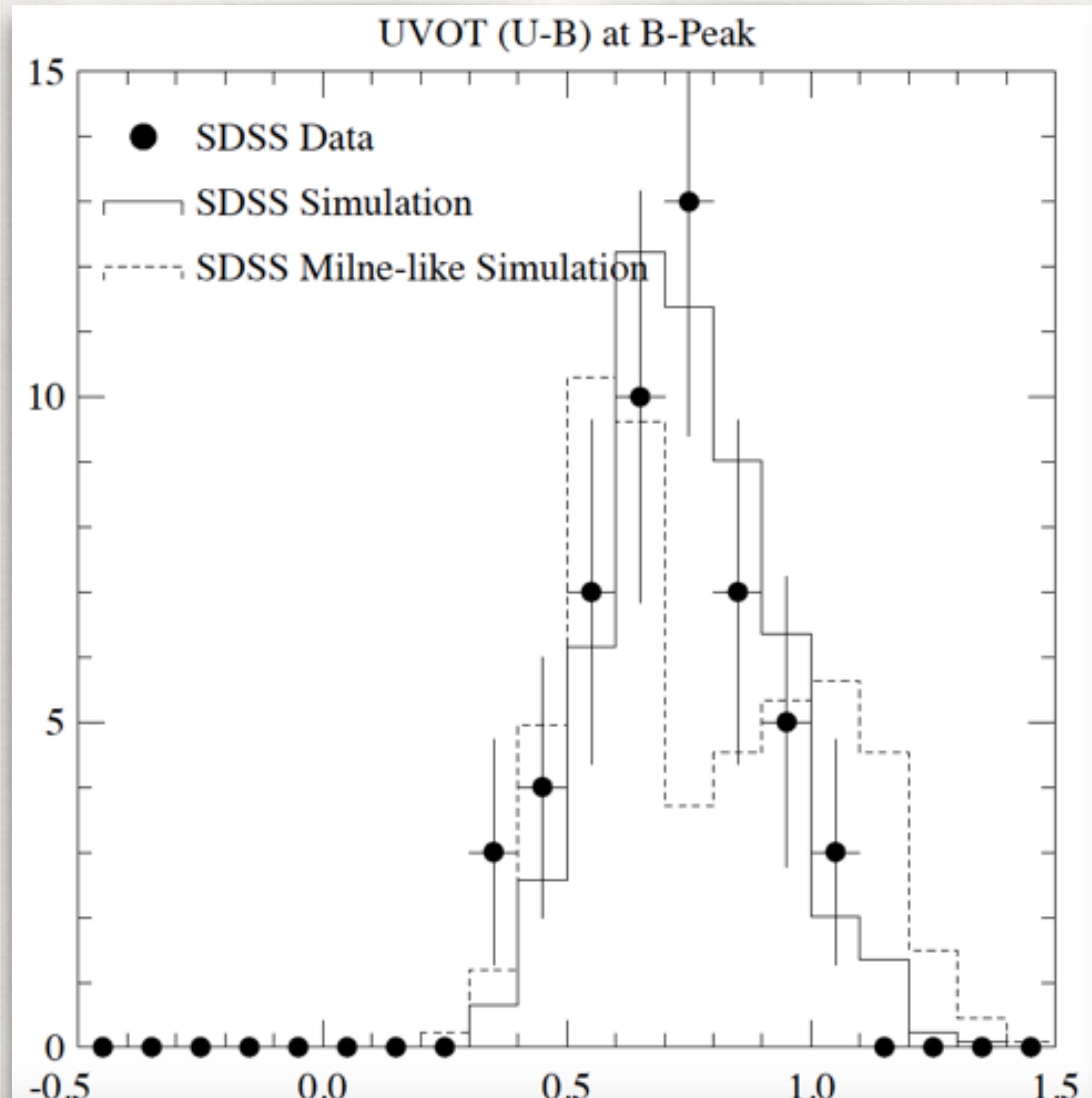

Milne Like (X1, MW, c=0, UV-Bimode) Variation Model
UVOT U-V Color at B-Peak
UVOT U-B Color at B-Peak
UVOT B-V Color at B-Peak
Color (mag)

SURVEY EXPECTATIONS AND DATA ANALYSIS

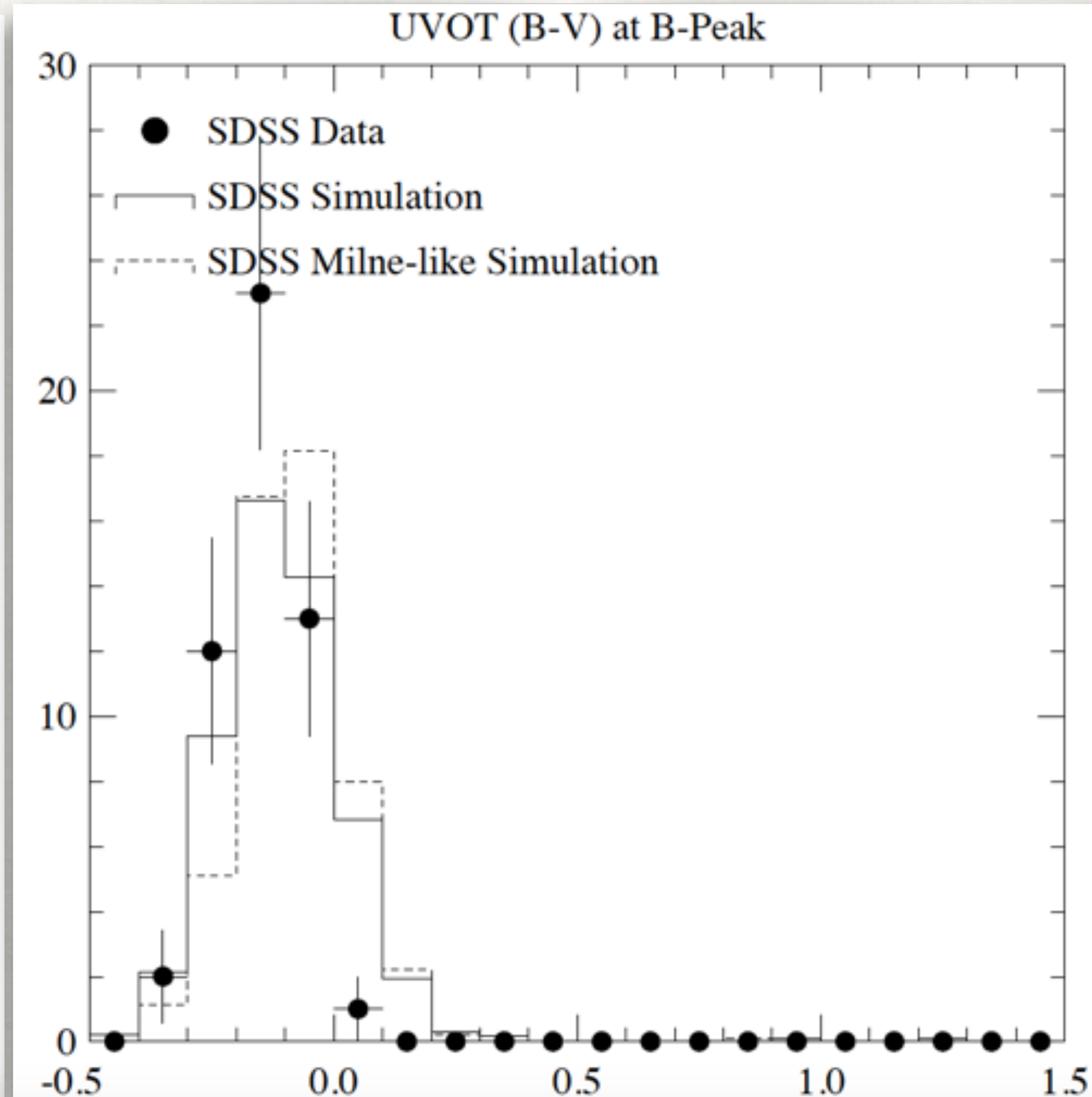
- Simulate these two models in the SDSS and SNLS surveys.
- For SDSS 0.3<z<0.4. Lower redshift is when the rest frame U-filter overlaps with the observer SDSS g-filter. Higher redshift cut is when SDSS SNIa light curves start to get ragged.
- For SNLS 0.3<z<0.7. High redshift is when the rest frame B-filter stops overlapping with the observer SNLS z-filter and we can no longer get a rest-frame B-filter magnitude.
- Only consider the most securely spectroscopically typed SNIa.
- Basic requirements for the light curves (at least 5 observations, observations before and after peak, S/N > 1 in u, z filters, S/N > 3 in g,r,i filters)
- Fit with the Salt-II model to extract X1, c.
- Do synthetic photometry on the resulting Salt fit to extract rest frame U,V,B-filter magnitudes and thus the U-V, U-B, and V-B colors at B-peak.
- Same analysis in data and simulation


UVOT (U-V) at B Peak
SDSS Data
SDSS Simulation
SDSS Milne-like Simulation
15
10
5
0
-0.5
0.0
0.5
1.0
1.5

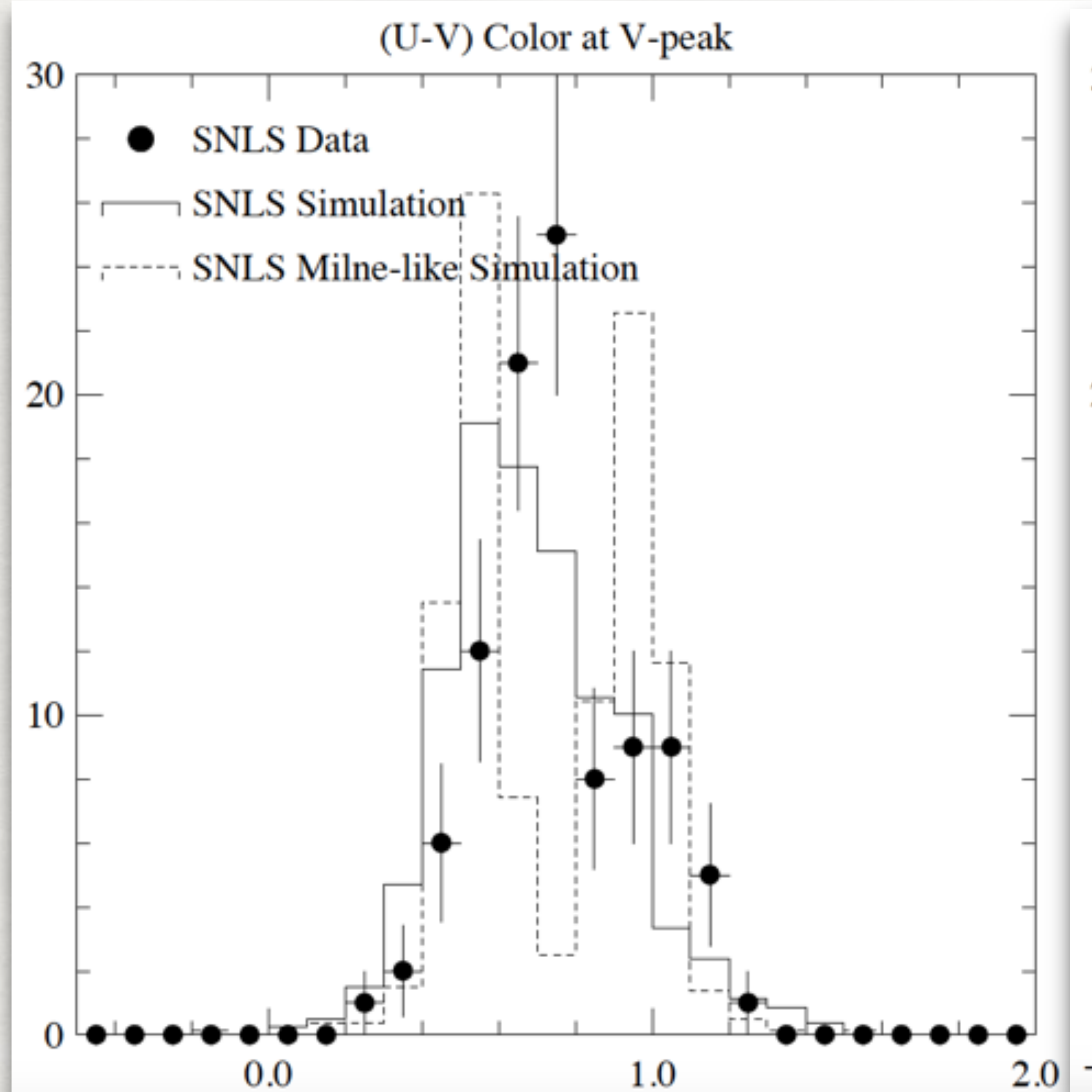
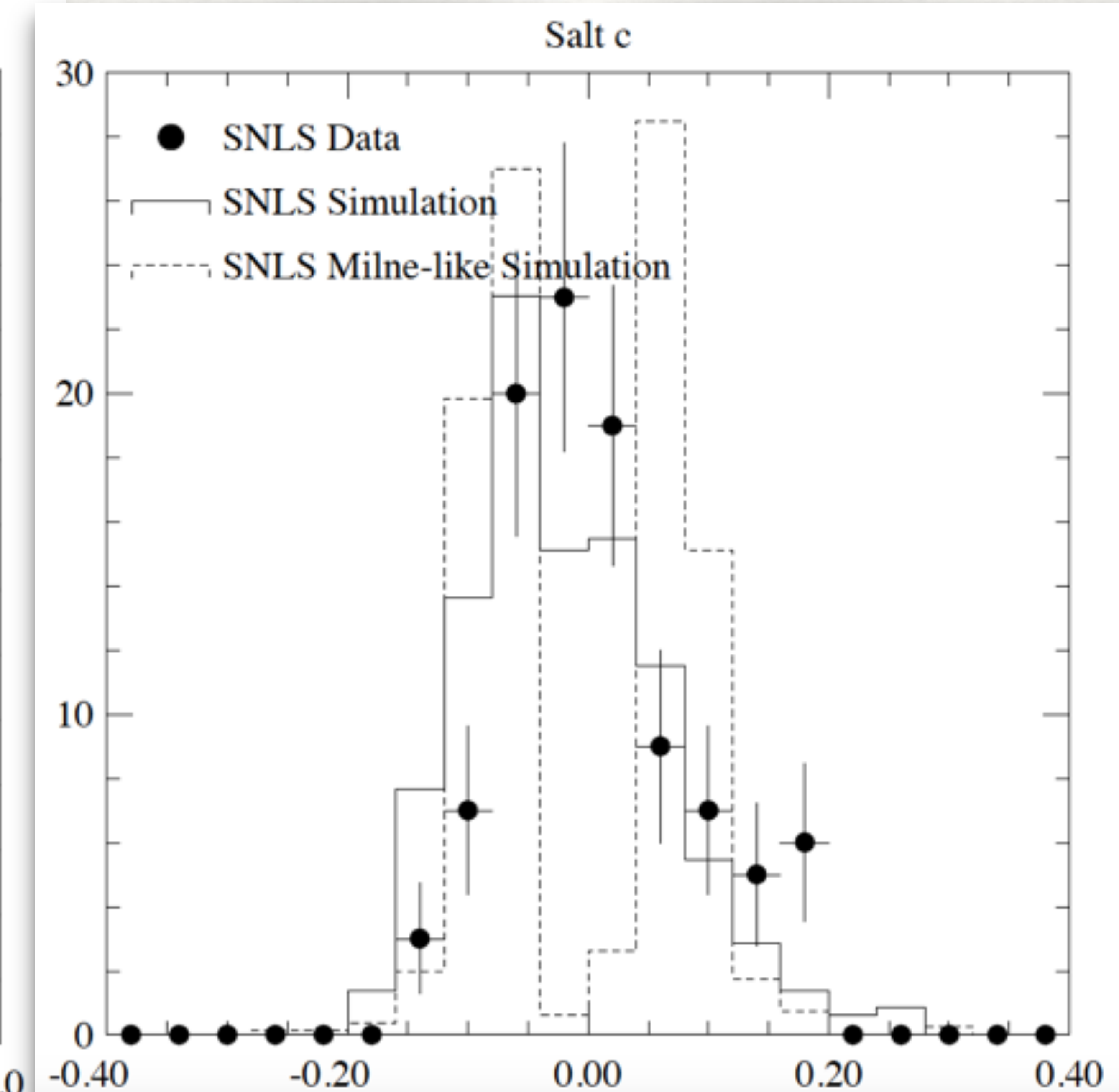

Salt c
SDSS Data
SDSS Simulation
SDSS Milne-like Simulation
15
10
5
0
-0.40
-0.20
0.00
0.20
0.40

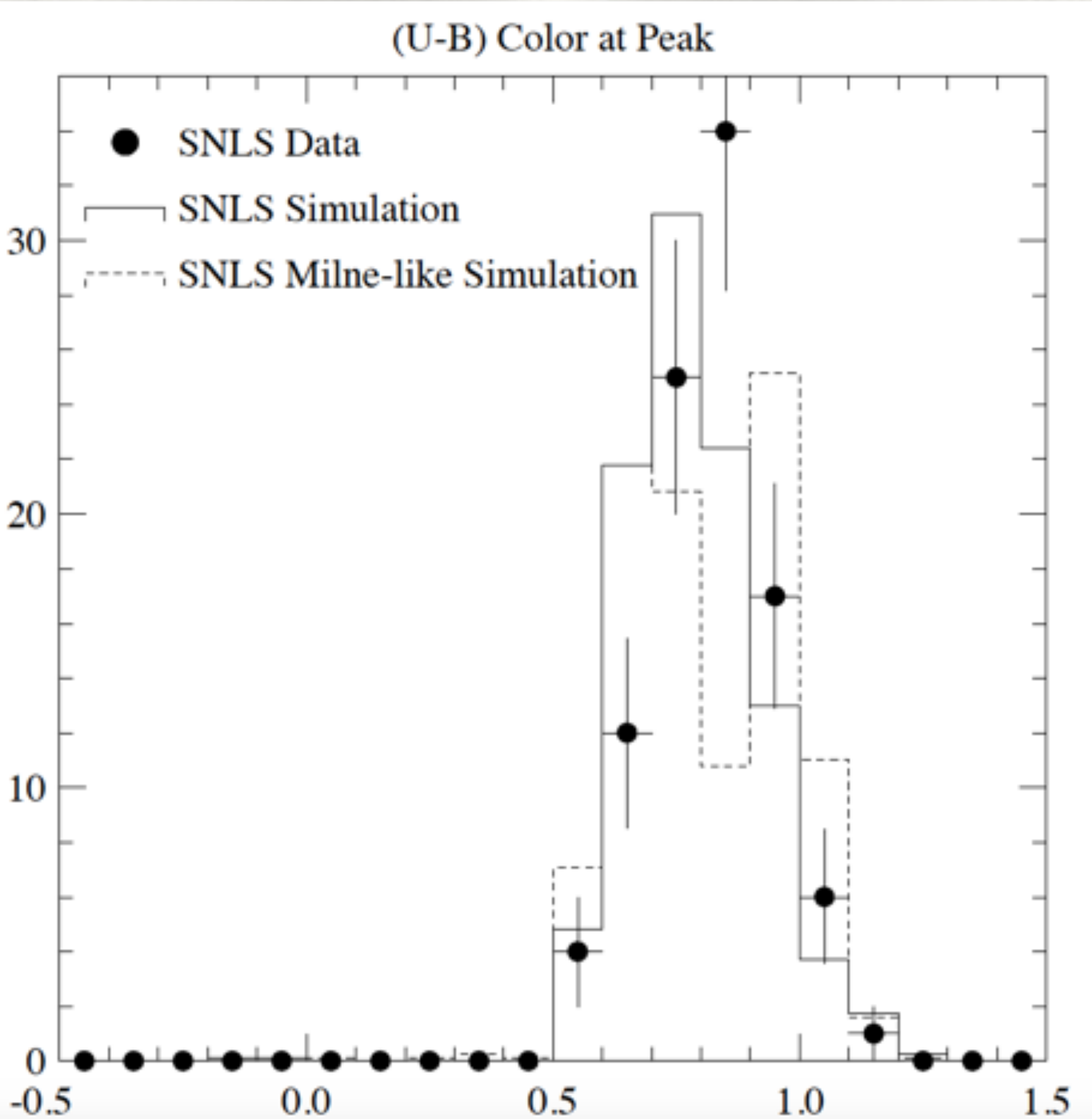


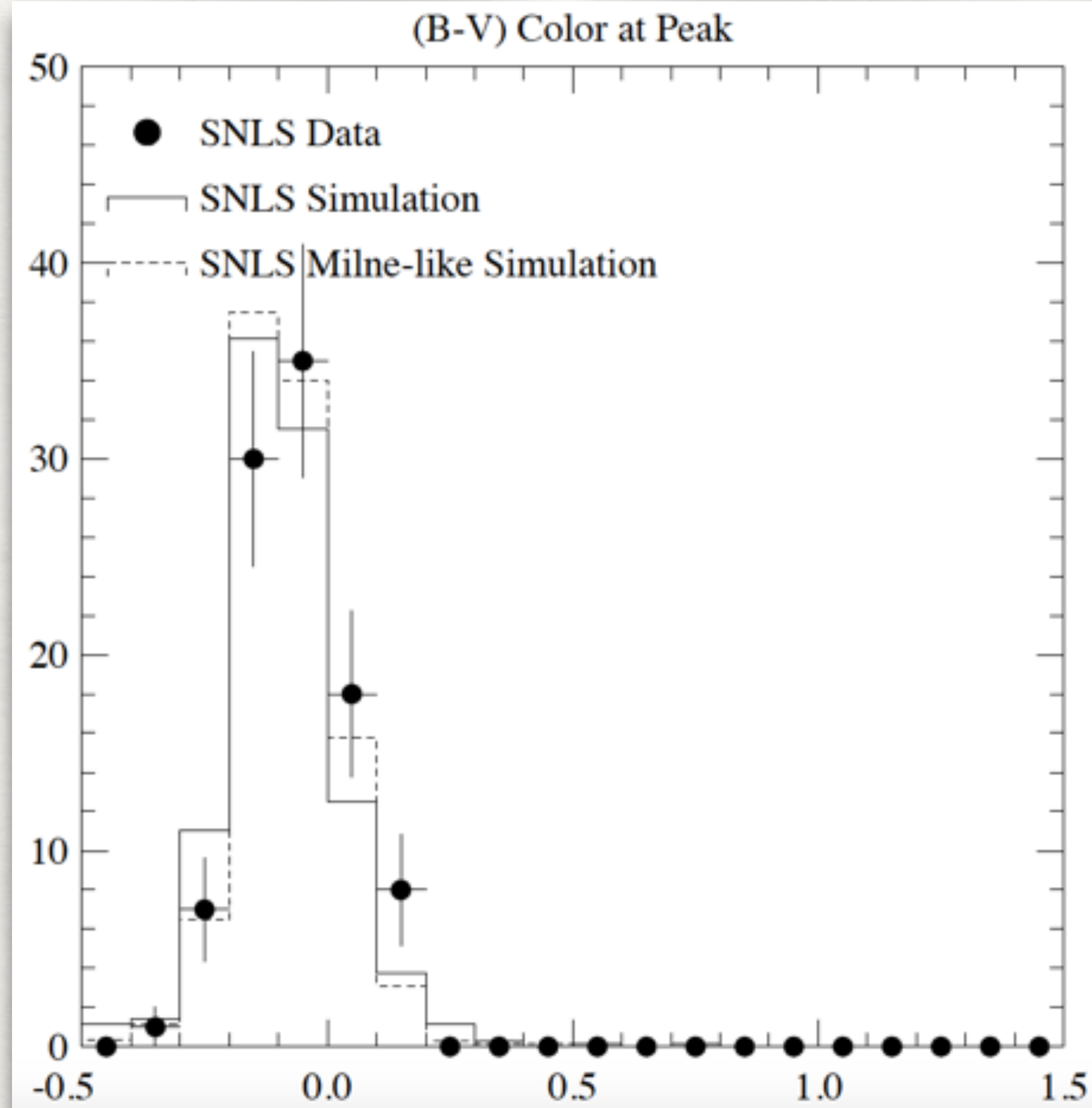
UVOT (U-B) at B-Peak
SDSS Data
SDSS Simulation
SDSS Milne-like Simulation
15
10
5
0
-0.5
0.0
0.5
1.0
1.5



UVOT (B-V) at B-Peak
SDSS Data
SDSS Simulation
SDSS Milne-like Simulation
30
20
10
0
-0.5
0.0
0.5
1.0
1.5

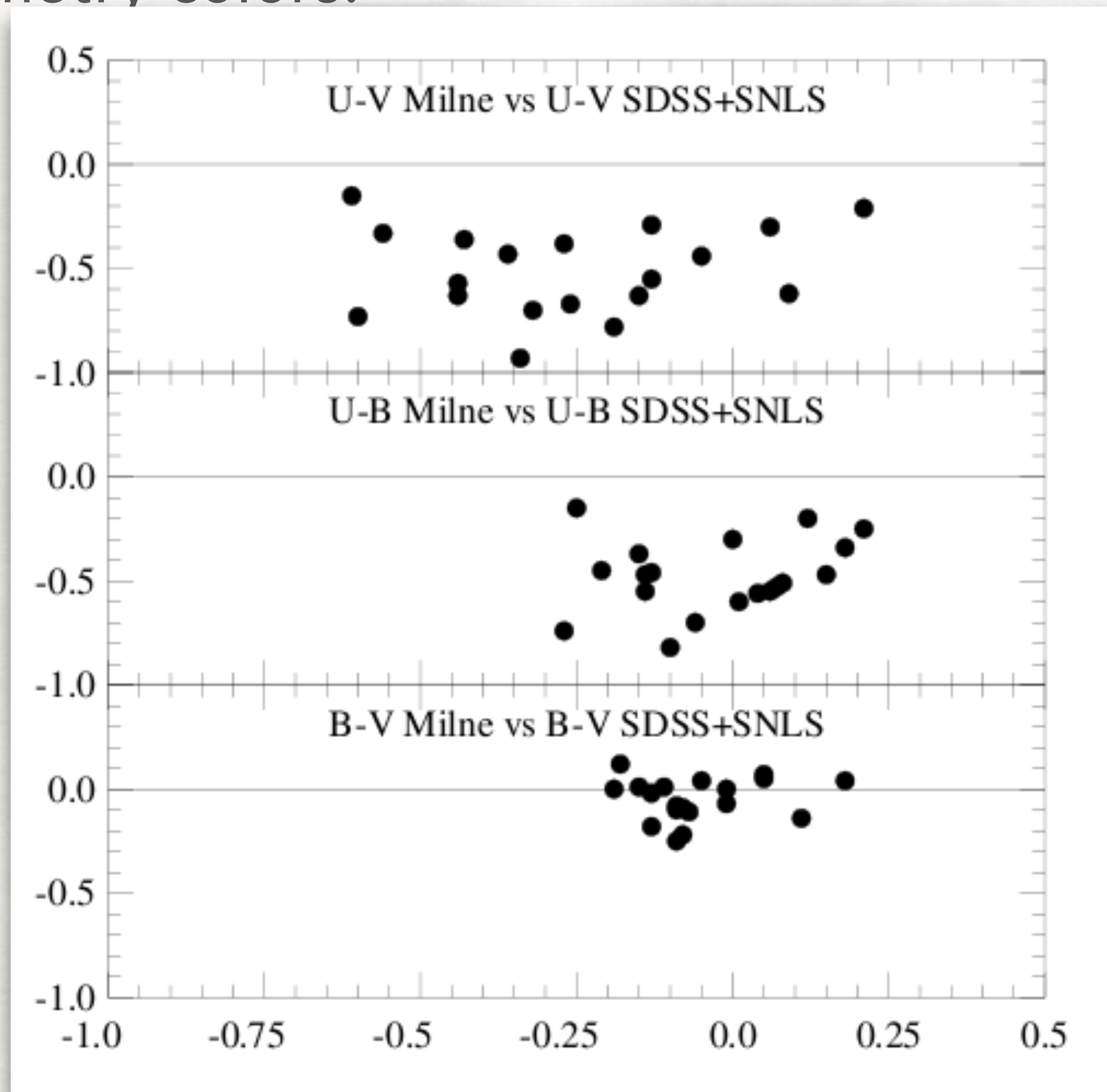

(U-V) Color at V-peak
SNLS Data
SNLS Simulation
SNLS Milne-like Simulation
30
20
10
0
0.0
1.0
2.0

Salt c
SNLS Data
SNLS Simulation
SNLS Milne-like Simulation
30
20
10
0
-0.40
-0.20
0.00
0.20
0.40


(U-B) Color at Peak
SNLS Data
SNLS Simulation
SNLS Milne-like Simulation
30
20
10
0
-0.5
0.0
0.5
1.0
1.5


(B-V) Color at Peak
50
SNLS Data
SNLS Simulation
40
SNLS Milne-like Simulation
30
20
10
0
-0.5
0.0
0.5
1.0
1.5

- 59 SNIa in SDSS and 99 in SNLS
- Simulation is about 15x data and scaled to the data
- No hint of bimodal ultra-violet as observed by Milne
- Good agreement with the Salt II model which has higher dispersion of SNIa in the ultra-violet than in the visible
- Other checks, redshift distribution, fitted X1 distribution, fitted accuracy on the peak time agree well between simulation and data.

- 19 of the Milne SNIa also appear in the SDSS and SNLS sample. Compare UVOT spectrophotometry colors with the SDSS and SNLS photometry colors:



- No obvious correlation between the two. Points to a problem in the UVOT spectrophotometry?

TO DO

- Need to limit how much of the bimodal distribution, we are not seeing the “blue” peak which Milne says should be dominant in our redshift range, there could be.
- Clearly we think the claim in Milne is not correct.
- Writing paper. About 10% done.